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Request for grant of a patent

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16 SEP 2003

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Cardiff Road
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1. Your reference

594

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2. Patent application number
(The Patent Office will fill in this part)

0321658.7

16SEP03 E837625-1 C12133
P01/7700 0.00-0321658.7

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3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

SOUTH BANK UNIVERSITY ENTERPRISES LIMITED
103 BOROUGH ROAD
LONDON SE1 0AA
GB

Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

6543714001

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4. Title of the invention

BIFILAR TRANSFORMER

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5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

COHEN, ALAN NICOL
2 GROVE PLACE
TATSFIELD
Nr. WESTERHAM
KENT
TN16 2BB

Patents ADP number *(if you know it)*

6963557001

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6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
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Continuation sheets of this form	
Description	7
Claim(s)	3
Abstract	1
Drawing(s)	2 + 2

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10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
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11. I/We request the grant of a patent on the basis of this application.

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Date 15/07/03

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A. N. COHEN 01959 577172

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Bifilar Transformer

(a) Field of the Invention

The present invention relates to a Digital Subscriber Line (DSL) transformer particularly operating in frequencies between 26kHz to 10 MHz but the invention can be extended to frequencies up to GHz range.

(b) Background of the invention

The transformer was invented by Michael Faraday in 1831. It is noted that the original designs of the transformer were intended mainly for power applications. This design is bulky and cumbersome as it involves a nucleus of ferrite surrounded by many turns of copper. Actually it has been kept with very little variation for more than a century in spite of a manifold of uses ranging from high voltage to sophisticated micro-electronic equipment.

The use of Broadband ADSL technology has increased dramatically. Moreover, DSL requires the use of Broadband access telecommunications transformers able to deal with large bandwidth. ADSL stands for Asymmetric Digital Subscriber Line because this provides more capacity in the "downstream" band than in the "upstream" band by using mainly echo cancellation to allocate the two bands. ADSL transformers have line-side inductances ranging from a few hundred of microhenries to a few millihenries. They do not need to carry DC; however they are gapped to control their inductance within a ±5% to ±10% range. Leakage inductances are roughly proportional to line-side inductances, ranging from a few microhenries to a few tens of microhenries. ADSL systems employ echo cancellation in the frequency range where the upstream and downstream signals overlap, making distortion a critical factor. Typical distortion requirements are –85 dB maximum THD for the CPE end and –80 dB THD for the CO end; both measured with a 15Vp-p signal at 100 KHz.

Limitations exist in the operation of ADSL services today because of inefficiencies in the line interface circuitry which is based on the traditional technology, as described above, to provide the required functions of safety isolation, impedance matching and signal filtering. In addition, the line interface is based on line interface transformers which are labour intensive products to manufacture and utilise expensive raw materials; copper for the transformer windings and magnetic materials for enhanced signal coupling properties. Wire wound transformers make use of standard magnetic interface and constitute the current 3D solution.

The ADSL line interface is characterised in terms of its size and effect on the overall system performance. The performance is proportional to the transmission speed distance. The present invention is dealing with all required parameters of line interface providing a Broadband signal transformer with an electrical safety barrier.

The transformer used in ADSL applications is used in the last stages of the line side. A common function of an ordinary transformer is to increase or decrease the input voltage. However in the transformer for ADSL applications, signal transmission and isolation are the main functions. Signal transmission is possible if one has a good flux linkage. Current designs of transformer rely on wire-wound arrangements around a ferrite core and this results in an overall aspect ratio of the device of approximately 1:1, which is to say that the device is a three dimensional object with a shape resembling that of a cube.

Surprisingly we have found that it is possible to reduce the aspect ratio considerably [illegible]

conductive material and in which the primary circuit and the secondary circuit are substantially parallel and substantially in the same plane.

The electrically conductive material can be any electrically conductive material such as metal, conductive plastics, etc.

The transformer preferably comprises a primary circuit and a secondary circuit, each circuit being formed of a continuous electrically conductive material and the circuits are in the form of substantially parallel spirals of the material. The spiral can be circular, elliptical, square, rectangular, oval or non-regular.

The spiral preferably conforms substantially to a spiral formed by the polar equation $r(\theta) = \alpha\theta$, where θ is the angle in polar coordinates, r is the radius and α is a constant that regulates the number of turns and the spacing. Preferably the number of turns in the spiral is at least five.

The invention also provides a quasi planar transformer which comprises a plurality of layers with each layer comprising a transformer as described above and in which the primary circuits of each layer are connected together and the secondary circuits of each layer are connected and preferably the layers are substantially parallel. The layers can be connected in series and/or parallel.

A way to achieve this linkage is through a compact spiral arrangement, namely, if the primary and secondary are in the same plane. This leads to two parallel spirals (hence its name "bifilar" transformer). Connections in series of the bifilar coils improve the signal transmission. The arrangement increases the height of the device. However the

total aspect ratio defined as diameter: height of the device, is kept relatively large and for this reason it represents a quasi-planar transformer (QPT).

In order to improve this component, a 2D solution for replacing the transformer function consists of a planar structure with two coils in bifilar design characterised by the absence of a ferromagnetic element.

There can be typically at least 5 layers, e.g. ten or more; in general the more layers the better the transformer operation.

Features of the invention are that there is an absence of a ferromagnetic element and the production of a very low aspect ratio transformer device, e.g. an aspect ratio of 1:5 or less and preferably with an aspect ratio less than 1:10 or less than 1:20. The invention provides a transformer without a ferromagnetic (usually ferrite) element with low aspect ratio. It has the additional advantage in that the manufacturing process is amenable to planar film techniques and also to multilayered fabrication techniques. The substance of the invention is that a 3D ferrite-core based design had been replaced by a 2D multilayered design in which all planar layers are connected to each other in series. This invention is particularly useful in, but not restricted to, Asymmetric Digital Subscriber Line ADSL and Very High Data rate DSL (VDSL) applications. Surprisingly, it is found that removal of the ferromagnetic element and a low physical aspect ratio in the device is possible and therefore transforming action is observed.

A comparison with conventional transformers is shown in Table 1

Table 1

Technology	Conventional Wire Wound Transformer	Novel Circular Spiral Transformer
Description	Magnetic Interface	Air-cored
Design	3 D	2 D

A convenient design of the circuits is an Archimedean spiral with polar equation $r(\theta) = \alpha\theta$, where θ is the angle in polar coordinates, r is the radius and α is a constant that regulates the number of turns and the spacing, is considered. As the angle increases, so does the radius. In order for the multilayered bifilar transformer to be connected, many spiral layers are connected in series; this is exemplified below.

The invention is illustrated in the following examples:

EXAMPLE 1

Standard state-of-the-art 3D ADSL Transformer:

An ADSL modem sends signals to the telephone company between 26 KHz and 138 KHz and receives signals from 138 KHz up to 1.1 MHz and the standard transformer was tested throughout the ADSL bandwidth (26 KHz up to 1.1 MHz). The amplitude response for the primary and the secondary coil characterizes the transformation behaviour of the tested transformer (Fig. 2). A modulating signal was applied to the "device under test" and both primary and secondary amplitudes were measured versus frequency variations. This first example is the current state of the art and represents a wire-wound ferrite, three dimensional transformer with an aspect ratio of 1:1.

EXAMPLE 2

Circular Spiral Transformer:

Two spiral coils compose an air-cored transformer. It has some similarities with a standard transformer but the mode of operation is different. A standard transformer uses tight coupling between its primary and secondary windings and the voltage transformation ratio is due to turns ratio alone. In contrast, a spiral coil uses a relatively loose coupling between primary and secondary, and the majority of the voltage gain is due to resonance rather than the turns ratio. A normal transformer uses an iron core in order to operate at low frequencies, whereas the spiral coil is air-cored to operate efficiently at much higher frequencies.

Referring to Fig. 3, this shows the bifilar construction consisting of one layer and without a ferromagnetic core.

Table 2 shows the design specifications of the novel circular spiral transformer.

Table 2

Aspect ratio	**5: 1**
Design Dimension for lab testing	**[71.25 mm] X [70.875 mm]**
Coil thickness	**0.375 mm**
Air gap between the two coils (Primary & Secondary)	**0.5 mm**
Number of turns (same for each coil)	**18 turns**
Thickness of laminate	**0.1 mm**
Inner coils separation	**7.5 mm**

structure provides a certain degree of flux linkage and this can be improved by adding more layers to the invented device (multilayer structure, ref. Fig. 5).

EXAMPLE 3

Multilayered Circular Spiral Transformer

Fig. 6 shows the multilayered bifilar planar coil without ferromagnetic element which is compared with the standard 3D ADSL transformer and 10 layers were used. A significant improvement is noticed throughout the ADSL bandwidth. The more layers added the better the transformer operation.

The bandwidth considered for all the above measurements is: 26 KHz to 1.1MHz, which is divided in the upstream band (26 KHz to 138 KHz) and downstream band (138 KHz to 1.1MHz).

Claims

1. A transformer which comprises a primary circuit and a secondary circuit each circuit being formed of a continuous electrically conductive material and in which the primary circuit and the secondary circuit are substantially parallel and substantially in the same plane.

2. A transformer which comprises a primary circuit and a secondary circuit, each circuit being formed of a continuous electrically conductive material and in which the primary circuit and the secondary circuit are in the form of substantially parallel spirals of the material.

3. A transformer as claimed in claim 1 or 2 in which the spiral may be circular, elliptical, square, rectangular, oval or non-regular.

4. A transformer as claimed in claim 3 in which the spiral conforms substantially to a spiral formed by the polar equation $r(\theta) = \alpha\theta$, where θ is the angle in polar coordinates, r is the radius and α is a constant that regulates the number of turns and the spacing.

5. A transformer as claimed in any one of the preceding claims in which the number of turns in the spiral is at least 5.

primary circuits of each layer are connected together and the secondary circuits of each layer are connected.

7. A quasi planar transformer as claimed in claim 6 in which the layers are substantially parallel.

8. A quasi planar transformer as claimed in claim 6 in which the primary circuits and the secondary circuits in each layer are connected in series and/or parallel.

9. A quasi planar transformer as claimed in any one of claims 6 to 8 which comprises at least 5 layers

10. A quasi planar transformer as claimed in any one of claims 6 to 9 with an aspect ratio of 1:5 or less.

11. A quasi planar transformer as claimed in any one of claims 6 to 9 with an aspect ratio less than 1:10.

12. A quasi planar transformer as claimed in any one of claims 6 to 9 with an aspect ratio less than 1:20.

13. A transformer as claimed in any one of the preceding claims without a ferromagnetic element.

14. A transformer as claimed in any one of the preceding claims which is a Digital Subscriber Line (DSL) transformer.

15. An electrical circuit which incorporates a transformer as claimed in any one of the preceding claims.

ABSTRACT

A transformer for that has the characteristic of: being quasi-planar and not requiring a ferromagnetic element to concentrate flux. The magnetic flux is transmitted efficiently via induction and an arrangement in series reconstructs and improves the overall performance of the standard 3D transformer. The final dimensions of the bifilar transformer are such that the aspect ratio of the device is low and can be described as quasi planar.

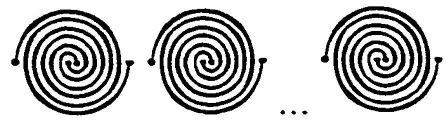

Fig. 1

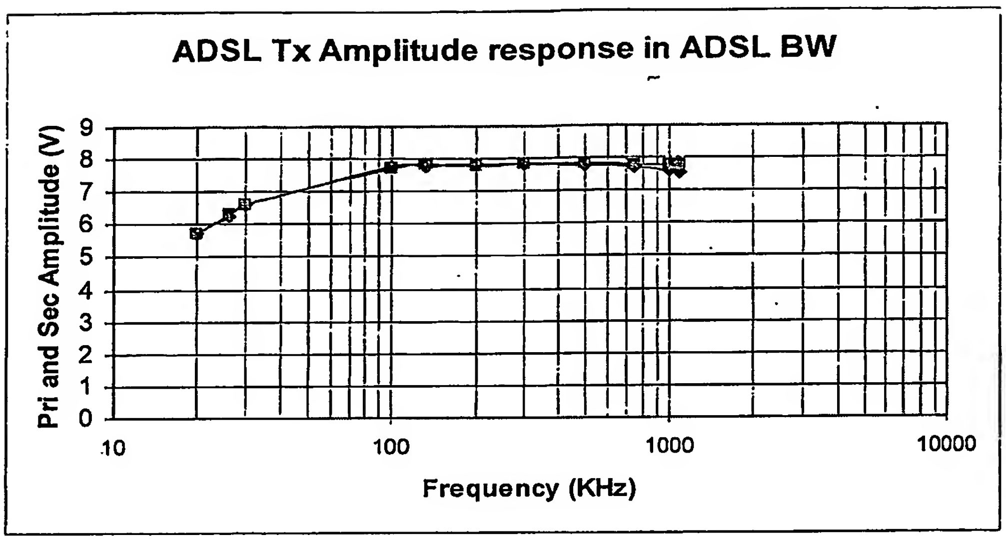

Fig. 2

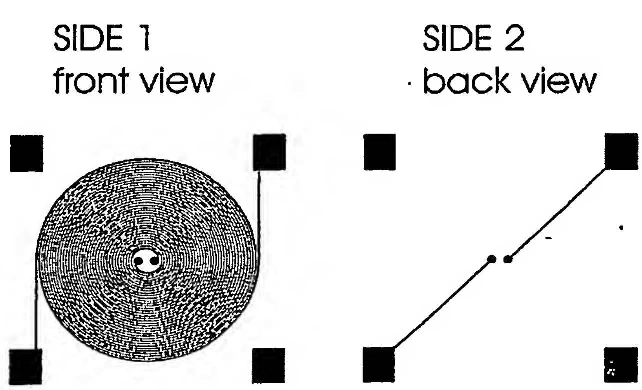

Fig. 3

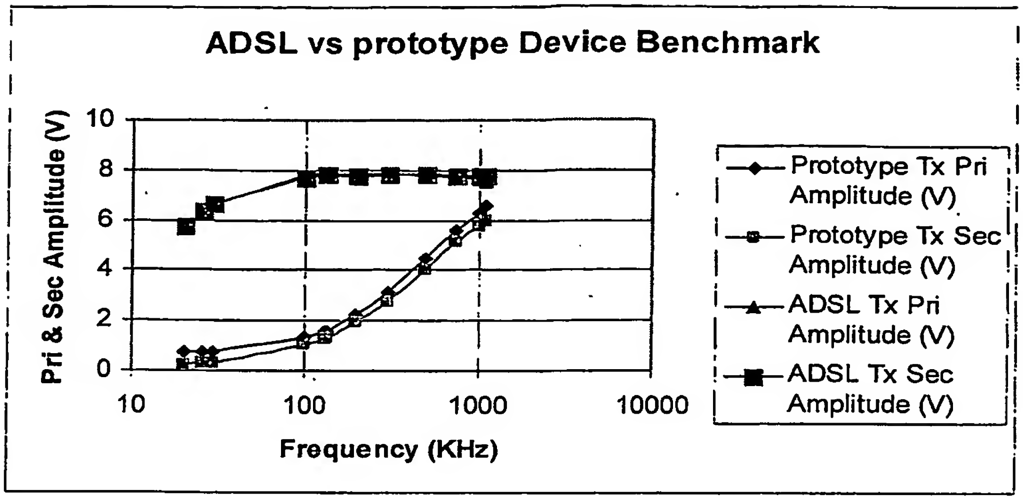

Fig. 4

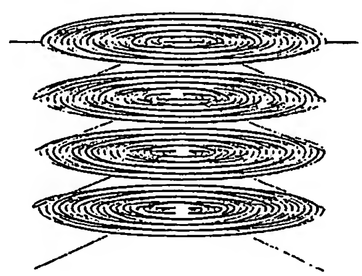

Fig. 5

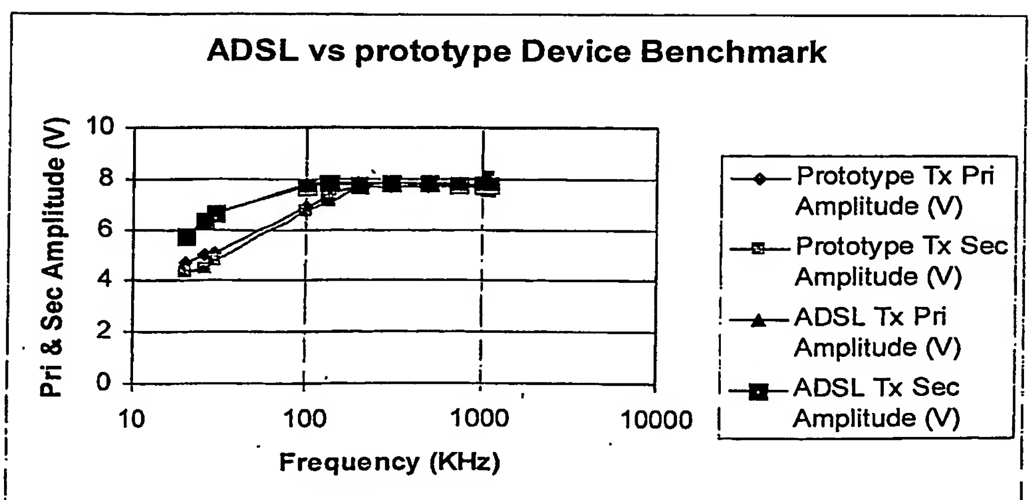

Fig. 6